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ABSTRACT

Based on the premise that knowledge of evolutionary theory is essential for understanding the natural world, this document was designed to assist science teachers and others as they consider the issues that influence the teaching of evolution. The position is taken that there is no conflict between data and sound theories based on science and religious beliefs based on the Bible. Information and perspectives are presented under the topic headings of: (1) "The Genesis of Genesis"; (2) "Early Science Interprets Genesis"; (3) "New Data"; (4) "Creationism versus Science"; and (5) "Two Kinds of Knowledge." References are listed and the National Science Teacher Association's position statement on the "Inclusion of Nonscience Tenets in Science Instruction" is included. (ML)

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ED280

MODERN SCIENCE AND THE BOOK OF GENESIS

BY

JAMES W. SKILTON

MODERN SCIENCE AND THE BOOK OF GENESIS

by James W. Skehan, SJ, PhD
Department of Geology and Geophysics
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Science Compacts from the National Science Teachers Association

During his service as president of NSTA (1985–86), Gerald Skoog sought to help teachers handle the issue of creationism in our schools. He drafted the NSTA Position Statement on the Inclusion of Nonscience Tenets in Science Instruction (p. 30), and worked to help science teachers address this controversy through sessions at our conventions.

One of these sessions, "Creation Science vs. Evolution," was presented at NSTA's 1985 Hartford, Connecticut regional convention by Dr. James W. Skehan, SJ. That session was so well received that we asked Dr. Skehan to work with us to create a document that would help teachers who had not been able to attend the convention.

The notes for the original presentation have been augmented and refined by Dr. Skehan, and other contributors have assisted in this process. Lawrence Bellipanni, Margaret McIntyre, Mary Beavis, Dorothy Gabel, Frederick L. Moriarty S.J., Charles L. Drake, Preston Cloud, and William D. Sullivan, S.J. all contributed valuable viewpoints. We consulted publications from the National Academy of Sciences and various technical journals to verify facts and quotations. Substantive editing was under the guidance of Mary Liston Liepold. The publication was produced on an Apple Macintosh Plus.

We are pleased to offer *Modern Science and the Book of Genesis* as the first in a new series of NSTA Science Compacts. We hope this series will provide educators with brief, cogent documents on important areas of concern in science and science education.

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Preface

Since Charles Darwin's *Origin of Species* was published in 1859, the relationship between science and religion has received considerable attention. During the last twenty years, when attempts to mandate the teaching of creationism and/or curb the teaching of evolution in the public schools have been persistent and widespread, conflicts between science and the doctrines of certain religious bodies have erupted periodically.

Science teachers, as well as policy makers, have been intimidated and distressed by this recurring conflict. The author of this publication, who is educated as a scientist and theologian, argues that the tension between science and religion that has historically surrounded evolution is unnecessary today. Both play an important role in the lives of many citizens.

It is my hope that the scientific and theological viewpoints presented in this small volume will be useful to science teachers and others as they consider the many issues that influence the teaching of evolution. Knowledge of evolutionary theory is essential for understanding the natural world and the processes that shape it. The future of human beings is tied to the present and future condition of the biosphere. Therefore, it is important that students have unrestricted opportunities to study evolutionary theory in the science textbooks and classrooms of this nation.

Modern Science and the Book of Genesis can help to bring about an intellectual environment in which every student can study evolution and other critical concepts of contemporary science.

Gerald Skoog
NSTA President, 1985–86

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Introduction

In recent years, I have watched with dismay and amazement as "scientific creationists" have succeeded in holding up the teaching of some major advances in geological science. Our response has been limited to a restatement of the principles of scientific methodology. We scientists have made little attempt to meet the creationists on their own ground, that is, on the nature of the book of Genesis as a cultural document. Jim Skehan is an outstanding Earth scientist and a theologian. His perspective is best highlighted by two quotations from his writings:

...if there is any consistent enemy of science and theology, it is irrationalism, even the irrationalism of religious men andwomen.

The Genesis narrative and the conclusions of science as to the age and origin of the Earth and of life, including that of humankind, belong to two interactive but distinct aspects of human understanding.

As scientists we ought to be secure in our own sphere, but as humanists we ought to try to understand at least something about the religious aspect of human understanding. A theologian's answer to fundamentalist misconceptions of science is long overdue. Jim Skehan is offering such an answer in a scholarly but most readable fashion. I am grateful for his efforts and for those of the National Science Teachers Association in publishing this pamphlet.

Professor Albert Bally, Chair
Department of Geology and Geophysics
Rice University, Houston, Texas

Foreword

The confusion generated by so-called creation scientists, who claim that the book of Genesis is a scientific document, requires today's teachers to be able to make a clear distinction between science and religion in a manner that does justice to both. A teacher must be able to help young people from every possible background to recognize that there is no conflict between data and sound theories based on science and religious beliefs based on the Bible.

Many sincere young people today face the same apparent conflict that I faced as a high school and university student in the 1940s, when Catholics were encouraged to interpret Genesis in a rather fundamentalist way. Thanks to a number of excellent teachers, I learned to rely on scientific methods to explain how our earth originated and evolved, and the origins of human life and other life forms. And I learned about the human authorship of scripture, that is, its historically conditioned character, as I also learned of and accepted its divine inspiration.

The reconciliation of faith and reason can bring the student out of a state of confusion about important areas of life portrayed by fundamentalists as contradictories. Instead of having to choose between the book of God's revelation and the "book of nature," as our ancestors called the natural world, the student can appreciate and learn from both, or at least understand the position of those who do.

Throughout the ages both Christians and Jews have looked to the Bible as a guide and support for their religious lives. Some, going further, have used the biblical writings to calculate the antiquity of the Earth and of humankind. Reasonable people used the sources of information that they had, before science had begun to produce reliable data about the age and history of the Earth and its life forms, and other aspects of the natural history of the Universe.

Over the past 150 years, however, advances in scientific research have brought to light evidence that the Earth is nearly five billion years old, and that during much of that time various kinds of life were evolving from simple to more complex forms. The earliest life forms yet discovered are about three and a half billion years old, and the record in the rocks tells us that we have been around for at least two million years.

As a result of these advances, the evolution of life forms has become widely accepted as a reasonable explanation for the progressively more complex fossils preserved in the rocks through geological time, and as an explanation for the diversity of modern organisms. As ideas concerning evolution have developed from the study of geology and biology, those who believe in the Bible as the word of God have taken up positions along a spectrum of beliefs. At one end are the so-called "creation scientists," who maintain a literal interpretation of the Genesis creation narrative despite the evidence from science and other fields of study. These individuals interpret the results of scholarly research as a threat to their religious beliefs, and maintain that no reconciliation is possible between belief in the Bible and belief in certain theories, such as the theory of evolution. On the other end are those in mainstream Christianity and mainstream Judaism, who find no conflict between biblical teachings and scientific theories regarding evolution and the great age of the Earth. In between there are a significant number of fundamentalists and evangelicals who hold a modified literal interpretation of Genesis and accept the standard geological data on the age of the Earth.

The term fundamentalism is used in at least two related but clearly distinguished senses. It may designate a conservative type of Christian thought that became influential in the second half of the nineteenth and first half of the twentieth centuries. The people to whom this name is applied today commonly feel it to be a hostile term implying narrowness, bigotry, obscurantism, and sectarianism.

It is also the name of a specific conservative movement begun in the United States in 1909 with its own organizations devoted to propagating a definite program of five points of doctrine set forth as fundamental. Its pivotal point is the literal inerrancy and infallability of the Bible. One of the most famous fundamentalists of this type was William Jennings Bryan, who won the State of Tennessee's case in 1925 against John Scopes, a public high school teacher charged with teaching evolution.

It is generally conceded, however, that the effect of the Scopes "Monkey Trial" was to discredit fundamentalism in the public mind. Thus with time the overt conflict between fundamentalism and science has decreased and the central body of conservative evangelical interpretation has generally surrendered on the point of evolution, the major focus of the earlier controversy. Many "fundamentalists" today, especially those who accept the results of science, prefer to be called "conservative evangelicals."

Among evangelical Christians there is a range of widely held theories relating the interpretation of Genesis to the findings of modern science. Of these, only fiat creationism, which adopts the Ussher-Lightfoot chronology described on page 18, rejects evolution entirely.

Fiat creationism, the most rigid of them all, is the specific, programmatic fundamentalism upheld by Henry Morris, its contemporary champion. Morris scathingly denounces the other, more liberal positions fundamentalists have developed, including the Gap Theory, which suggests that billions of years may have occurred between Genesis I:1 and Genesis I:2, and the Day-Age Theory, which interprets the biblical days of creation as geological epochs. Morris objects to efforts by liberal fundamentalists to harmonize the Biblical chronology with geological time because he believes that such accomodation is inevitable followed by acceptance of the evolutionary system.

These pages will summarize the basis for the position of the majority that it is perfectly reasonable in the twentieth century to accept both scripture and science. Like many others, I accept the Bible as a guide to my relationship with God, and I accept science as a guide to the origins of the Universe, the Earth, and humankind.

One of the profound divisions within Judaism and within the Christian religions hinges on the creationists' claim that all truth, both religious

and scientific, is revealed in Genesis. Theistic evolutionists, on the other hand, regard Genesis as a religious document composed by inspired authors to present a religious message. They grant to science its proper role of unravelling the history of the formation of the Earth, the Universe, and living things, and understand that its established theories do not threaten our religious beliefs.

Mainstream biblical scholars focus on the intentions of the authors of Genesis, and of the other four books that comprise the Pentateuch, or Torah, the first section of the Bible. These books were written by deeply religious authors who saw history not merely as events that happened to people, but as the record of God's dealings with a special people. Genesis was written to tell the Jews who they were, how and why they were chosen as God's people, what marvelous things God had done for them, and what God expected of them. It was not composed as history for its own sake, but as history whose purpose was to communicate religious messages.

In recent decades scientific discoveries have permitted us to calculate the age of the Earth and to trace the physical evolution of its rock formations and the life forms preserved within them. Before these discoveries, our ancestors had no specific reason not to understand the six days of creation literally. Early biblical commentators recognized, as we do, that Genesis 1 to 11 is an imaginative narrative that uses poetic language and contains much imagery and many figures of speech. Still, in the absence of scientific evidence, these commentators followed a sound course of interpretation for their times in accepting its chronology at face value.

Today we have information that was not available to them, knowledge which must be factored into our interpretation of scripture. We cannot embrace contradictories. If a scientific fact is accepted as true, its contradictory cannot be true. Thus we must take into consideration in explaining the Bible facts which were unknown a few generations ago. Naturally, our interpretations will differ from older ones.

The Genesis of Genesis

Today we have more information available to us about how the Bible itself came into being than did our predecessors. In earlier centuries the Bible was accepted as God's word in the narrow sense, as though God had dictated every word. If Moses was the author of Genesis, and if its first chapters describe events that nobody but God could have seen, then, it was concluded, God must have revealed Genesis just as we have it. Modern biblical scholarship, on the other hand, maintains that Genesis was written under divine inspiration, but that the human writers assembled their materials and carried out their work in the same way that writers have in every age. Today we have direct evidence to show that the authors of Genesis derived their materials from written and oral sources that were readily at hand, such as the Babylonian creation myth and the Mesopotamian story of a "worldwide" flood.

Chapters 1 to 11 of Genesis blend fragments of myth, legend, and folklore, whereas the patriarchal stories in Chapters 12 to 50 remind us of family sagas. Israel's historians made use of materials of all kinds, often modified from those of her pagan neighbors or captors. These include ancient creation stories, genealogical lists, songs, proverbs, legends, and records of customs, institutions, and idioms. All contributed to the authors' purposes and were refashioned accordingly.

External Evidence

In many cases the biblical authors quoted a traditional source. Unfortunately, these writers did not usually inform us when they were quoting or adapting parallel writings, as was done in Genesis 1:1-2:4a, the creation narrative. By comparing the Genesis text with the Babylonian creation myth, *Enuma Elish*, ("When on High"), we can see both parallels and pronounced differences.

Archaeological discoveries of tablets recording the Babylonian creation story have shed light on that story and its relation to Genesis. *Enuma Elish* is an epic poem of a little over a thousand lines recorded on seven clay tablets. The first fragments were discovered by Austen H. Layard, Hormuzd Rassam, and George Smith, during expeditions between the years 1848 and 1876 among the ruins of the great library of King Ashurbanipal (c. 668-630 B.C.) at Niniveh. Subsequent explorations through 1929 led to the discovery of all the remaining tablets except for a large portion of Tablet V.

Enuma Elish	Genesis
An account of the birth of the gods and various conflicts between them	
Divine spirit and cosmic matter are coexistent and coeternal	Divine word creates cosmic matter and exists independently of it
Primeval chaos; Ti'amat, enveloped in darkness	The earth is a desolate waste, with darkness covering the deep (tehom)
Light emanating from the gods	The creation of light and the separation of light and darkness
Marduk's work of creation (a)The creation of the firmament	The creation of the firmament and the dividing of the waters
(b)The creation of dry land	The creation of dry land, the sea, and plant life
(c)The creation of the luminaries	The creation of the luminaries, the creatures of the sea, and the birds
(d)The creation of man The building and dedication of Esagila, the temple complex	The creation of land animals and human beings; God instructs Adam and Eve and blesses them
The gods rest and celebrate; the hymn to the creator, Marduk	God rests from all his work and sanctifies the seventh day
Epilogue	

George Smith of the British Museum, the first to publish an account of the epic, translated and discussed all of the pieces which had been identified prior to 1876. The resemblance of their contents to the initial chapters of the Bible had immediate appeal to a very wide circle of students. Since then, this story has been copied and translated by many Assyriologists, especially as new, related tablets have been found (Heidel, 1951).

The left column of the table on page 12 outlines the story of the origin of the gods as presented in the *Enuma Elish*. Marduk was the creator of the Earth in this account, an agent repudiated by the authors of Genesis, who offered a new theology of creation by the one God of Israel. The well known topics and sequence of Genesis are presented in the column on the right. The authors of Genesis have borrowed many of the topics of the older Babylonian story, but rejected those which involve a contrary theological perspective.

In the language of drama we might say that the props are the same in these two creation narratives, but the characters are very different. The primitive cosmology of the Bible authors' time is used to teach the origin of all things in God, emphasizing God's power as transcendent Supreme Being. Whereas the earlier, pagan, Babylonian creation epic, which is generally dated from at least 2000 B.C., depicted creation as the result of a struggle between the gods and the forces of chaos, the biblical account stresses the effortless activity of the one God. The imagery borrowed from *Enuma* and other accounts serves the authors' polemic against the error of polytheism. The table highlights the similarities of sequence, as well as the contrasts in religious points of view.

Internal Evidence

We may discover what kind of document Genesis is from a study of the text itself. Some stories, such as the creation narrative of Chapters 1 and 2, consist of two parallel accounts woven together by the biblical authors. Differences between these accounts in style, in detail, and even in the name for God permit us to distinguish component parts. Evidence derived from literary analysis of the Bible has led most non-literalist scripture scholars of the past 200 years to interpret Genesis as a composite of several documents, or *traditions*, as they are called. The most significant traditions in Genesis are referred to as J (Yahwistic), E (Elohistic), and P (Priestly). Although it is not a tradition as such, we also refer to R, a redactor, or later editor, who refashioned the material belonging to the several traditions into the form in which it has been recorded in the earliest known manuscripts comprising the Hebrew Bible. On the basis of archaeological evidence and the early written records of near-Eastern peoples, we can date these traditions as far back as the tenth century B.C.

The earliest tradition is called Yahwistic, or J (scholars follow the German spelling, *Jahweh*,) because it uses the divine name said to have

been first revealed to Moses on Mount Sinai. This tradition is generally attributed to a Judean writer of the tenth century B.C., working during the reign of Solomon (c. 960-920 B.C.). The Yahwist gave Genesis its narrative framework. He uses a distinctive vocabulary and a vivid, colorful style replete with anthropomorphism, as when he describes God walking in the garden of Eden.

The Elohistic tradition, E, uses *Elohim* as its title for God, a name whose root meaning appears to designate power—"the Force," we might say today. It also has a distinctive vocabulary, and a somber style, which depicts the relationship of God with mankind as less intimate than it appears in the Yahwist passages. God remains invisible, speaking from the midst of fire or cloud, and frequently speaks in dreams, or acts through the agency of angels.

The Priestly tradition, P, with its obvious concern for liturgy, imposed an order and system on Genesis, beginning in the first chapter and running throughout, so that even the narrative has a legalistic and liturgical bias. This document, as we have it, probably dates from the period of the exile of Judah in Babylon (587-538 B.C.), though it incorporates much earlier material.

The redactor, or final editor, put Genesis and the other books of the Pentateuch into essentially the form in which they occur in the most ancient Hebrew manuscripts we know, from about 400 B.C. The ideas stressed by this editor are mainly those of J and P, with some elements of E.

The documentary hypothesis is the most satisfactory explanation of how the basic materials of the Pentateuch came to be assembled into Genesis and the other four first books of our modern Bible. Despite creationist claims that the hypothesis has been disproven by conservative biblical scholars, it is accepted today by the vast majority of those in the mainstream of scriptural studies.

Genesis is a cherished literary and religious document which was shaped by human authors using the data available to them in their time. The Genesis account, in turn, was a major part of the data that scientists had to work with, before the recent explosion of scientific knowledge.

Early Science Interprets Genesis

The Flood

Early scientists interpreted Genesis in light of the science of their day. The Jesuit Athanasius Kircher (1602-1680), a renowned German geologist and amateur Egyptologist, examined the story of Noah's Ark in a systematic fashion.

Taking the recorded dimensions of 300 cubits, which he interpreted as 450 feet (135 meters, or about one and a quarter football fields), Kircher computed how many animals the Ark might hold. Ignoring fish and other creatures that did not need the Ark to survive the flood (including the innumerable tribes of insects), Kircher listed all the rest of the animate life forms he knew: about 130 kinds of mammals, 150 birds, and 30 reptiles.The drawing on pages 16 and 17 is based on his calculations. He listed all the supplies and equipment that would be needed by Noah's family and the livestock for a year. He calculated that three decks would hold it all, if each contained 300 stalls, and he set aside space for passageways, ventilation, and hatches. The top deck was the Ornithotropheion, the bird area, with room for Noah and his family; the middle deck, the Bromatodocheion, held supplies; and the lower deck, the Zootropheion, or animal area, held the rest of the animals. Elephants, camels, rhinos, and lions were housed amidships on deck three, directly opposite the sheep, cattle, goats, and deer.

On the basis of his knowledge of living forms and his computations, Kircher concluded that the authors of Genesis intended a factual narrative. It is understandable Kircher came to that conclusion at that time.

In the next century, Carl Linnaeus (1707-1778), father of modern taxonomy, compiled data on all 15,000 creatures known to him, more than 40 times the number of animals Kircher knew. Today's estimate is about 30 million species (Diamond, 1985). Thus in the course of time, biblical scholars, aided by the investigations of science, came to understand that the authors of Genesis presented the story of the flood and Noah's Ark for the religious message it contained, and not for the purpose of recording factual natural history.

The creationist's perspective is based on the fundamental assumption that today's Bible in an approved English translation is intended to be taken literally. This is the only legitimate approach, they claim, because

Deck One
Eagles
Vultures
Hawks
Hens
Peacock
Parrot
Magpies
Kingfishers
Partridge
Pheasant
Grouse
Pelicans,
Spoonbill
Kitchen
Larder
Singing birds
Fowl
Pigeon, Doves
Gyr-falcons, Harpies
Exotic birds such as Crakes, Shrikes, Titmice, Wrynecks
Deck Two
Cheese
Butter
Goat
Bread
Pears
Seeds
Spices
Fire-wood
Ropes
Empty room
Mech. tools for future
Pigeons
Chickens
Dried fish
Can-dies, honey
Salt, metal
Olive oil
Hand mills
Iron tools
Cloth, utensils
Agricul-tural tools
Deck Three
Elephant
Camels
Dromedary
Horses
Asses
Onagers
Cats
Monkeys
Rabbits
Squirrels
Indian pigs
Conies
Empty room
Cattle
Goats
Sheep
Bison
Elk
Gazelle
Bushbucks
Hippos
Crocodiles
Otters
Beavers
Cistern

In the 17th century, Athanasius Kircher set out to calculate how the Ark could hold all the Earth's land creatures. He translated the biblical 300 cubits into 135 meters, and drew a detailed plan to that measure, with three decks each holding 300 cubicles. Everything fit perfectly— animals, food, water, supplies, and Noah's extended family. Fortunately for him, Kircher only knew 340 kinds of animals. Today we know about 30 million.

the Bible is the word of God, a factual narrative, which for all practical purposes was dictated word for word by God. Creation science implies that the Bible must not be interpreted by the same techniques which are applied to other literary works.

The Age of the Earth

One key creationist assumption is that the biblical narrative contains the basis for computations of the interval of time from the creation of the Earth to the birth of Jesus Christ, and that this interval plus the date A.D. is the true age of the Earth. On this basis creationists hold that the Earth may be as young as 6000 years.

It is important to understand at least the basics of how this figure of 6000 years came to be accepted. James Ussher (1581-1656), Archbishop of Armagh and Vice-Chancellor of Trinity College, Dublin, a distinguished biblical scholar, compared three different astronomical cycles, the lunar, the solar, and the 15-year Roman cycle, with an interpretation of the timing of early biblical events. As a result of these painstaking methods, and having no reason at that time to question the literal accuracy of the biblical narrative, Ussher concluded in 1650 that the world was created early Saturday evening, October 22, 4004 B.C. From 1701 well into the 20th century, Ussher's date for creation was commonly added as a marginal note to the Authorized Version of the English Bible. According to Stephen Jay Gould, it was still being printed in the Gideon Bibles in 1977 (Gould 1977, p.147).

A number of current textbooks blur Ussher's calculations together with those of his contemporary, John Lightfoot. Lightfoot, who distinguished himself as a biblical scholar and eventually became Vice-Chancellor of Cambridge, published his observations eight years before Ussher. He specified the time of the creation of Adam (not of the Earth) as early morning at the autumnal equinox of 3928 B.C. Lightfoot arrived at his conclusion by totalling the ages of individuals in the Bible and adding the date, 1644, to give a sum of "5572 years just finished since the Creation, and the year 5573 of the world's age now newly begun this September at the Equinox" (Brice, 1982).

Tallying up such great intervals of time to produce a chronology was no small task. Ussher compared four different versions of scripture to arrive at the period between the creation and the flood, each yielding a different date: the Hebrew, 1656 years; the Samaritan Pentateuch, 1307 years; the Septuagint as computed by Eusebius, 2242 years; and an

Ethiopic text, which placed the interval at 2262 years. Ussher selected the Hebrew text as the most reliable. Lightfoot, on the other hand, gives only one set of dates and ages. In the course of time, more than 300 such lists of chronologies have been attempted, and nearly all of them arrive at a figure near 6000 years from the time of creation to the present. Present-day creationists are sometimes willing to accept a figure as high as 10,000 years.

New Data

Evidence from the Earth

While Lightfoot and Ussher were calculating the Earth's age from scripture, others had already begun to look to the Earth itself for answers. Six years before Lightfoot's death in 1675, Nicolaus Steno established the foundations for the science of stratigraphy, and surmised that fossils were the remains of ancient animals, rather than God's practice creations snuffed out by the flood.

In 1785 James Hutton proposed the concept of uniformitarianism: that the physical composition of the Earth was the result of gradual geological processes operating over long periods of time, and still in operation today. Engineer William Smith made stratigraphic analyses in 1799 that confirmed Steno's hypotheses. After demonstration by Hutton's friend James Hall, and inclusion in Sir Charles Lyell's *Principles of Geology* (1830-1833) the idea began to gain respectability.

In the course of the nineteenth century physicists made calculations based on the theories of Galileo, Newton, and others, and proposed estimates ranging from 75,000 to 40,000,000 years for the age of the Earth. Lord Kelvin held up the upper end in an address before the 1897 annual meeting of the American Association for the Advancement of Science. Although Kelvin was not yet aware of its implications, Henri Becquerel had just discovered radioactivity in uranium salts, in the same year (1896) in which Marie Curie isolated radium and Wilhelm Roentgen discovered the X ray. Together, these discoveries would make it possible to measure the length of time since specific rocks were formed.

Ernest Rutherford, in 1905, was the first to suggest that radioactive materials could be used to date rocks. He succeeded in dating a uranium sample in his Montreal laboratory the following year. Bertram Boltwood, the discoverer of the first isotope (an isotope of thorium which he called "ionium"), also published the ages of dated minerals in the ensuing years. In 1913 Frederick Soddy refined their processes by clarifying the nature of isotopes. Already it was becoming clear from empirical evidence that the Earth and its components dated in the billions of years.

Scientists use the amounts of parent isotopes and daughter products present in a rock sample to gauge the time between that rock's

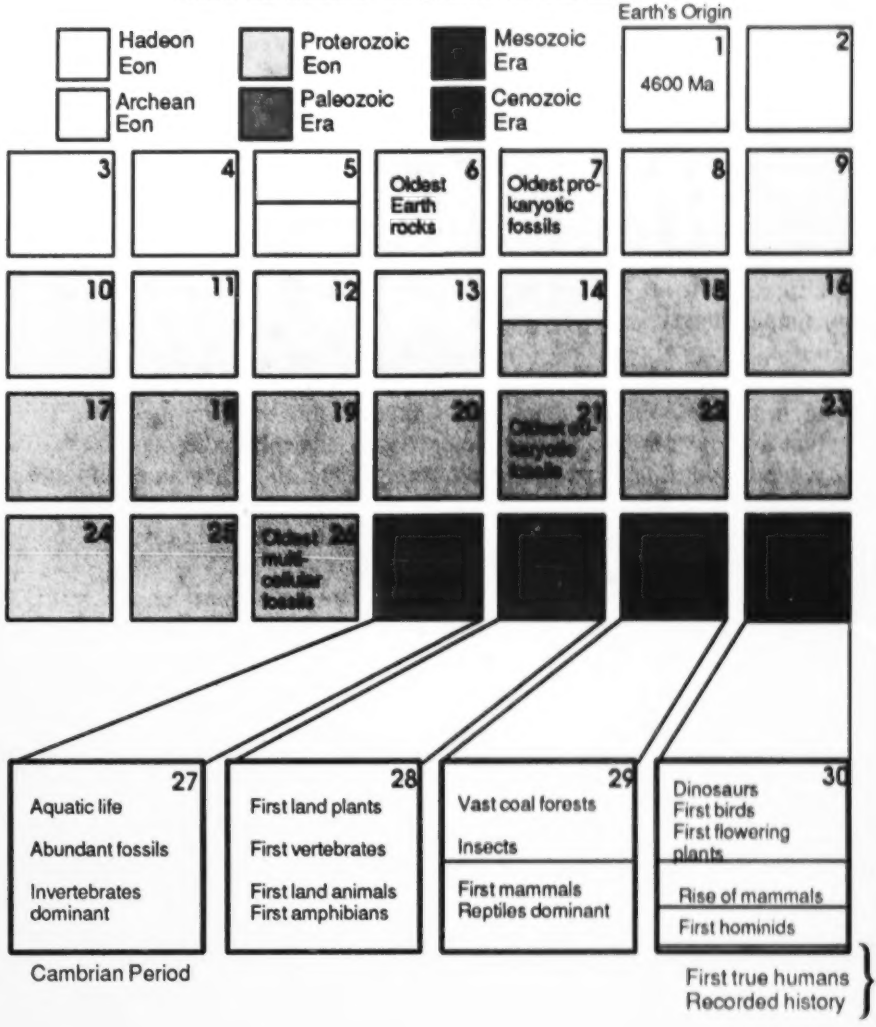
crystallization and the present. Measurements based on the known decay rates of uranium, rubidium, potassium, and samarium reveal the dates of the formation of the substances in which they occur, and by inference, of any other rocks that are obviously related in age. When we date the crystallization of a granite, for example, we also know that the surrounding sedimentary rocks into which the granite was intruded when it crystallized must be older than the granite itself. We can date sedimentary rocks from the fossils they contain. But if these strata overlie, and thus must be younger than other radioactively dated rocks, we can establish an absolute age range, if not a precise date of formation, for the sedimentary rocks, even if they themselves contain no datable materials.

Age-dating of meteorites has revealed that they are all somewhere in the vicinity of 4.5 billion years old, no matter what their composition. The fact that there are no known meteorites of any other age, regardless of when they fell to Earth, suggests strongly that they originated in other bodies of the solar system that formed at the same time the Earth did. If so, then the meteorites also help us to calculate the age of our Earth.

Earth lead falls on the same isochron (a line on a chart connecting points derived from measured isotopic ratios which represent the same time or age) as the lead in meteorites, and thus indicates an age for both of 4.6+ billion years. We infer from this that both came from the same primordial source and at the same time. Since quantities of uranium 235 and uranium 238 increase as we move backward in time (and uranium decays into lead at a slow but precisely known rate) we may assume that quantities of lead 207 and lead 206 were proportionally smaller than they are now. As we compute the decreasing quantities of lead 207, we conclude that the Earth's supply must have been zero 5.6 billion years ago. On the basis of these two measurements we conclude that the Earth must be younger than 5.6 billion years and older than 4.5 billion.

Geologists studying fossil-bearing sediments have worked out a "clock" which is accurate enough to distinguish the relative ages of rock units as small as a few meters thick which may represent periods of time of less than a million years. (A million is a large number, of course, but a million years is only about 1/5000th of the Earth's history.) The entire geologic record of these sediments has been analyzed and subdivided into a scheme of of eras, periods, and absolute ages. In the figure on page 22 the most eventful divisions have all been collapsed into the last three days. Perhaps the most important time boundaries are those at 570

One Month Calendar of Earth



Ma = Millions of years ago

million years ago (or 570 Ma, the beginning of the Cambrian period), 225 Ma (the Permian extinction), and 65 Ma (the extinction of the dinosaurs and the rise of mammals). The Pleistocene deposits, extending back to about two million years ago (2 Ma) contain the earliest remains of human life yet recognized.

The oldest Moon rock yet dated is about 4.4 billion years old, and the oldest Earth rock about 3.9 billion years. The oldest traces of life—bacteria-like structures found in a torrid region of Western Australia whimsically named North Pole— are also about 3.5 billion years old. At 570 Ma, the beginning of Cambrian time, we first notice the appearance of relatively sophisticated organisms, existing in such profusion and variety that we can safely describe the Cambrian seas as teeming with life.

Evidence from the Creatures

It is clear from the fossil record that over the eons life forms have changed dramatically but gradually from the simple single-celled organisms of 3.5 billion years ago into animals as complex as human beings. About the same time Steno was learning matter's laws from the rocks, a French naturalist, Georges Buffon, began to notice some interesting things about animals. Why are the limbs of creatures as diverse as the whale, the bird, and the human modeled on the same general plan? If each had been specially created for its own habitat, as had been previously supposed, it might be expected to have a unique design. And why do pigs have two toes which never touch the ground, and human beings have organs, like the appendix, for which no purpose has yet been discovered?

Erasmus Darwin, grandfather of Charles, and Buffon's student Jean Baptiste Lamarck were among the nineteenth-century scientists who paved the way for Darwin's *Origin of Species* in 1859. But because the discoveries of paleontology and stratigraphy were still almost unknown, Darwin (who called his theory "descent by modification") worried about the scarcity of evidence for the intermediate stages of modification. The fossilized remains of Archaeopteryx, a creature midway between reptile and bird, provided the first-found link in 1861. Like every such discovery in the years that followed, it initiated a search for other forms which would have occupied the spaces before and after it.

Creationists then and now have seized on Darwin's doubts as

ammunition against his theory. But the record is there, for their examination and ours. Although gaps still remain—for your students to fill someday?—the museums of the world contain over 100 million fossils which have been identified and dated by thousands of paleontologists. From these studies, and those of tens of thousands of other scientists, we can trace a complex and awe-inspiring process.

During the first two and a half billion years of life organisms lacked hard parts, such as skeletons and shells, which form easy-to-recognize fossils. Moreover, geological dating for this period must be done on the basis of episodes of igneous intrusion, metamorphism, and mountain building, rather than the more constant rate of sedimentation, so the record for this period is still being revealed, as we develop the tools to analyze it. Since 570 Ma, the record is relatively easy to read.

Trilobites first appeared and became important in the Cambrian period; fishes in the Ordovician; trees and land plants in the Silurian and Devonian; dinosaurs in the Triassic through Cretaceous; and mammals in the Triassic. Human beings came on the scene in the Pleistocene epoch—the last ten minutes of the thirtieth day, in the calendar on page 22. The final 30 seconds represent the span of recorded history.

Creationism Versus Science

Creationism: The Appeal to Authority

The creationist response to all this evidence from physics, geology, biology, and the related sciences is still the one that last-ditch literalists were struggling to maintain in the nineteenth century. If there is any contradiction between a literal interpretation of the Bible and knowledge derived from scientific studies, the latter cannot be true because God's word cannot be false. Adam was created in God's image and likeness; therefore humans can in no way have evolved from lower mammals. The Earth and everything on it was created in six days. In the creationist view, all the progress that science has made in recent centuries is reduced to "interpretations" of scientific data that "appear to be" in conflict with the "facts" of Genesis. This is especially the case with regard to the creation stories, which deal both with the creation of the Earth and with the special creation of Adam and Eve.

These assumptions are central issues for us because they relate not only to the validity of studies in the life sciences and Earth sciences, but also to the understanding of God's word through a sound and reverent application of critical method. It is of great importance because the creationist position basically holds that all of the most important truths are explicit in the Bible, and that many conclusions or theories based on the results of scientific studies, such as evolution or the age of the Earth, are illusory.

The conflict of scriptural data with empirical data, and the refusal to distinguish between them, has led to numerous well-known tragedies and seriously impeded the progress of science. Sincere people of earlier generations did the best they could with what they knew. But we must not allow the clock to be turned back now, by the willfully ignorant of our own time.

Science: The Appeal to Evidence

Although creationists claim not to be opposed to science, it is clear that they reject one of the most important parts of the work that scientists do, namely the development of models and theories to explain data. Creationists assume that whoever accepts evolutionary theory cannot accept divine creation, and explain that the "evolutionary prejudice of liberal scholars" invalidates their objectivity (Morris, 1976). They either do not grasp or choose to ignore the nature of theory.

Characteristically, creationists claim that "there is no scientific proof" for evolutionary theory, to which they are unalterably opposed. But no respectable scientist claims that the evidence for a particular theory of evolution is so compelling and complete that it should be regarded as proven—or completely understood, including its mechanism. Strictly speaking, a theory cannot be *proven* in the same sense in which a mathematical theorem can be proven. This is not a judgement of any particular theory, but only a statement of the way human knowledge develops. Theories are erected on evidence; as studies proceed, the evidence increases and the theories are modified. Our understanding grows.

At this point in time experts have presented evidence for evolution that is so massive and so convincing that the general validity of the theory is logically demonstrated. From Darwin to the present, the best available data at any given time have constantly served as a basis for modifying theories of the evolutionary process. A given theory of evolution in 1880 must be very different from one in 1980 or 2080, because, on the basis of new evidence, our understanding of the theory itself evolves. However, it is in the nature of scientific investigation that the strong corroboration of a theory is secured by evidence. Overwhelming evidence for evolution and uniformitarianism has come from molecular biology, embryology, taxonomy, genetics, zoology, comparative anatomy, physiology, geology, stratigraphy, paleontology and paleoanthropology, physics, chemistry, and astronomy.

The amount and variety of evidence tracing the persistent process of evolution throughout most of Earth history is so great that geologists generally accept evolution as "proven" —"proof" being a logical deduction as to the cogency of the evidence: a theory so convincing that prudence dictates acceptance.

One of the objectives of scientific investigation is to try to discover mechanisms; however, the demonstration of the logical validity of a theory is independent of the discovery of the mechanism. For example, plate tectonic theory has now been generally accepted among geologists, although its mechanism is not yet fully understood.

Two Kinds of Knowledge

The Genesis narrative, therefore, and the conclusions of science as to the age and origin of the Earth, and of life, including human life, belong to two interactive but distinct aspects of human understanding. Genesis should be interpreted as saying very little, if anything, of relevance today about the age and mode of origin of the Earth and living things. This is a proper subject only for geological and other scientific research, using methods that have been devised relatively recently.

The creation story is an anthropomorphic reconstruction cast into a framework of six working days and one sabbath day for rest. It is a prelude to religious history. Its purpose was not to convince the people of Israel that this was how things actually happened—much less to convince modern people. The ancient Hebrews were perhaps better aware than most of us today that the basic creation story was modeled on the well-known Babylonian myth of creation, which the authors of Genesis, after first excluding some unacceptable assumptions, followed topic by topic. However, the Genesis story emphasized those religious aspects of creation that distinguished Israel from her neighbors, especially those among whom she lived during the Babylonian exile.

The story of creation is a prelude to the story of Adam and Eve's fall and the consequent human estrangement from God. These events are introductory to the patriarchal narratives, and ultimately to the saving acts of Exodus. As salvation history, its message is a religious one.

If we were to misrepresent the Bible as a scientific presentation, rather than as a theological document of Judeo-Christian religious history, we would do a great disservice to religion. Religious persons have no reason to fear the results of scientific research, since these results cannot contradict authentic religious experience. It is important for both religious persons and scientists (by no means exclusive categories) to be clear about the differences between science and theology. Confusion on the part of creationists, politicians, and the general public bodes ill not only for the quality of science education but also for the good name of religion among thinking people.

Some of us have tended to feel superior to those whose truncated educations and benighted attitudes led to the dark ages of a few centuries

ago. Let me suggest that our educational systems may very well be on the threshold of a new and even gloomier Dark Age of the 20th and 21st centuries, unless the anti-intellectualism and confused thinking creationists produce is overcome. Since the overriding concern of fundamentalists is to preserve at any cost the inerrancy of the word of God as they understand it, they bring a tremendous zeal to their crusade. The problem is a cultural one with important educational implications. Scientists cannot address this problem through science teaching alone. It seems to me that if creationists and others who reject evolution are going to be reached at all, it will be by teachers who can address themselves to both kinds of knowledge.

The education of every science teacher who is likely to face the creationist mindset should include something about the premises and procedures of modern biblical scholarship, and the distinct roles of scientific knowledge and religious faith. The Bible has a very special place in our culture, and even students from non-fundamentalist backgrounds are often pleasantly surprised and relieved to learn that it in no way conflicts with science.

A sound and critical analysis of Genesis makes it clear that the authors of that book had as their main objective to produce a history of Israel which provided a religious message and guidelines to an intimate relationship with the personal God who made a covenant with Israel. It is equally clear from other considerations that the role of science is to investigate the universe, including Earth, and to understand how it came to be as it is. Religious persons who believe that God is the creator of the Universe and the author of the laws by which it operates should find no conflict between science and religion.

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NSTA Position Statement

Inclusion of Nonscience Tenets in Science Instruction
People have always been curious about the universe and their place in it. They have questioned, explored, probed, and conjectured. In an effort to organize their understandings, people have developed various systems that help them explain their origin, e.g., philosophy, religion, folklore, the arts, and science.

Science is the system of exploring the universe through data collected and controlled by experimentation. As data are collected, theories are advanced to explain and account for what has been observed. Before a theory can be included in the system of science, it must meet all of the following criteria: (1) its ability to explain what has been observed, (2) its ability to predict what has not yet been observed, and (3) its ability to be tested by further experimentation and to be modified as required by the acquisition of new data.

NSTA recognizes that only certain tenets are appropriate to science education. Specific guidelines must be followed to determine what does belong in science education. NSTA endorses the following tenets:

I. Respect the right of any person to learn the history and content of all systems and to decide what can contribute to an individual understanding of our universe and our place in it.

II. In explaining natural phenomena, science instruction should only include those theories that can properly be called science.

III. To ascertain whether a particular theory is properly in the realm of science education, apply the criteria stated above, i.e, (1) the theory can explain what has been observed, (2) the theory can predict that which has not yet been observed, (3) the theory can be tested by further experimentation and be modified as new data are acquired.

IV. Oppose any action that attempts to legislate, mandate, or coerce the inclusion in the body of science education, including textbooks, of any tenets which cannot meet the above stated criteria.

Adopted by the NSTA Board of Directors
July, 1985